

SYSTEMS AND METHODS FOR AERIAL DISPERSION OF MATERIALS

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BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to aircraft systems, and more particularly to aircraft systems that may be used for aerial dispersion of materials.

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2 Description of the Related Art

Aircraft are commonly employed for the aerial dispersion of liquid and/or solid materials such as fire retardant or fire extinguishing materials, oil dispersant materials, bio-remediation materials, fertilizer materials, herbicide materials, defoliant materials, pesticide materials, *etc.* For example, specially-equipped aircraft are used to carry and deliver fire retardant materials to the area of a forest or brush fire. Such fire-fighting aircraft are typically converted World War II era bombers or propeller-driven passenger or cargo planes that have a carrying capacity limited to 3000 gallons or less of liquid fire retardant material. These vintage aircraft typically deliver their load of fire retardant material by flying to the area of the fire and then making a low altitude bombing run over the fire that often requires steep dives and climbs to accurately deliver the fire retardant payload to a targeted fire hot spot. The nature of these low altitude bombing runs often result in g-force stresses that exceed the structural rating of these aircraft, weakening the structure of the aircraft and in some cases causing in-flight structural failures leading to loss of the aircraft and crew. A limited supply of vintage aircraft and the grounding of particular types of aircraft due to structural weaknesses has resulted in a shortage of fire-fighting aircraft.

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Many vintage aircraft are converted for aerial dispersion of materials by the permanent installation of material dispersion equipment. Modular aerial spraying

systems have also been developed for use in conversion of C-130 cargo aircraft for aerial spraying purposes. Known as the Modular Airborne Fire Fighting System (“MAFFS”), these systems employ portable pressurized tanks which are loaded onto a C-130 aircraft through the lowered rear cargo ramp of the aircraft. The lifting capacity of the C-130 aircraft limits the amount of water or water-based retardant which may be carried by the MAFFS aircraft to about 3000 gallons. Most MAFFS are “single shot” systems that discharge a full 3000 gallon load at one time, although there exist two load MAFFS units that may split a 3000 gallon load into two separate discharges. Because of their drop pattern, MAFFS are not typically used for support in residential areas or for initial attack on a fire, which usually require multiple drops from a single air tanker. In addition to limitations in MAFFS capacity and drop pattern, certain C-130 aircraft that are employed for MAFFS purposes have been recently grounded due to excessive stresses imparted on these aircraft when using them for aerial fire-fighting.

Specialized modern aircraft have also been developed for aerial fire-fighting purposes. In this regard, the Canadair CL-415 is capable of in-flight re-filling from large bodies of water, such as lakes. However, the CL-415 is very expensive relative to vintage aircraft, has a limited carrying capacity of approximately 1621 gallons of liquid fire retardant material, and the cost of obtaining and maintaining a state-of-the-art modern fleet of such aircraft would be prohibitive. Furthermore, such a fleet of fire-fighting capable aircraft is not needed all the time. Thus, the relatively small carrying capacity, specialized nature, and high cost of such aircraft prohibits large-scale deployment in an aerial fire-fighting fleet.

Further information on practices and condition of the aerial firefighting fleet in the United States may be found in *Federal Aerial Firefighting: Assessing Safety and Effectiveness*, Blue Ribbon Panel Report to the Chief, USDA Forest Service and Director, USDI Bureau of Land Management, December 2002.

SUMMARY OF THE INVENTION

Disclosed are methods and systems that may be implemented to allow rapid and temporary conversion of aircraft for aerial dispersion purposes, such as aerial fire-fighting. The aerial dispersion equipment of the disclosed systems and methods may be implemented using modular components that may be configured for compatibility with conventional cargo loading and unloading systems of modern aircraft, including side-loading cargo systems of wide body passenger and cargo aircraft having high lift capacities. In one embodiment, wide body commercial aircraft may be quickly and temporarily modified for aerial dispersion purposes, allowing a large fleet of high capacity aerial dispersion aircraft to be quickly assembled, for example, in response to a wildfire or other rapidly-developing emergency such as an oil spill, chemical or biological contamination incident, building or refinery fire, *etc.* After use, the aircraft may be rapidly de-modified and returned to original condition, *e.g.*, as commercial passenger or cargo plane, or as military transport or bomber. In another embodiment, such a fleet of aerial dispersion aircraft may be configured to operate in a coordinated manner, for example, as part of an aerial firefighting formation sharing common control such as ground control or lead aircraft that directs flight path and/or release of materials from individual aircraft in the formation. Military heavy lift aircraft (*e.g.*, including transport and bomber aircraft) may be similarly converted and employed, either in combination with or as an alternative to commercial aircraft.

The disclosed systems and methods may be configured to utilize relatively inexpensive modular equipment that may be quickly loaded onto and unloaded from an aircraft using the conventional cargo systems of the aircraft, advantageously allowing modification and de-modification of side-loading aircraft that do not have a wide rear cargo ramp such as possessed by C-130 aircraft. For example, modular and connectable units in the shape of conventional cargo pods may be rapidly loaded and unloaded through side cargo doors into the cargo hold of high lift capacity wide body commercial aircraft (*e.g.*, such as 747, 767, 777 or MD-11 aircraft) or high lift capacity wide body

military/cargo aircraft (*e.g.*, such as C-5, C-141, *etc.*) in a manner consistent with normal cargo loading operations to provide a removable and re-useable aerial dispersion system having a capacity much larger than the capacity of existing aerial dispersion systems. In those embodiments where the modular units are configured in the shape of conventional cargo pods, they may be employed with a wide variety of aircraft types that employ the same type of cargo pods regardless of the capacity of a given aircraft. Furthermore, the modular nature of the cargo pods allows a given aircraft to be provided with an aerial dispersion system of desired or customized capacity and/or capability to fit a given application, *i.e.*, by loading a desired number and type of modular units required to provide the desired capacity and capabilities of the system.

The high capacity aerial dispersion systems that may be provided using the disclosed systems and methods make possible aerial dispersion techniques that do not require low altitude or high angle dives or climbs to apply aerial dispersants to targets, such as fire hot spots. In this regard, high lift capacity wide-body aircraft may be provided with aerial dispersion systems having a capacity of aerial dispersant material that is many times the capacity of existing aerial dispersion systems. Using these high capacity aerial dispersion systems allows high volumes of aerial dispersant to be effectively applied to a target drop point location from a higher altitude without requiring steep diving or climbing maneuvers that may result in unacceptable g-force stresses. Furthermore, since the disclosed aerial dispersion systems may be rapidly installed on conventional commercial and/or military aircraft, it is possible to provide a large number of high capacity aerial dispersion aircraft that may be deployed together to provide a very large volume of aerial dispersant simultaneously and/or sequentially onto a given target or targets, *e.g.*, to rapidly and effectively suppress a wildfire. Following the aerial dispersion mission, the disclosed aerial dispersion systems may be rapidly de-installed or removed from the aircraft so that the commercial or military aircraft may be quickly returned to normal configuration for resumption of conventional flight operations.

In one respect, disclosed herein is an aerial dispersant holding tank configured as a pseudo cargo container and including a first flow opening for dispersant material. The

first flow opening may be configured for flow of dispersant material during aerial
dispersement of the dispersant material. The first flow opening of the aerial dispersant
holding tank may be further configured to be coupled to at least one other aerial
dispersant holding tank to provide a dispersant material flow path from the aerial
5 dispersant holding tank to the second aerial dispersant holding tank.

In another respect, disclosed herein is an aerial dispersion system configured for
use with a host aircraft, including: one or more aerial dispersant holding tanks
configured as pseudo cargo containers; a dispersal regulator configured to be coupled to
10 the one or more aerial dispersant holding tanks; and an airborne dispersal device
configured to be coupled to the dispersal regulator.

In another respect, disclosed herein is an aircraft-based material dispersion
system, including: a host aircraft; one or more aerial dispersant holding tanks disposed
15 within the host aircraft, the aerial dispersant holding tanks being configured as pseudo
cargo containers; a dispersal regulator disposed on the host aircraft and coupled to the
one or more aerial dispersant holding tanks; and an airborne dispersal device disposed on
the host aircraft and coupled to the dispersal regulator.

In another respect, disclosed herein is a method of converting at least one host
aircraft for aerial dispersion of material, including: removably disposing one or more
aerial dispersant holding tanks within at least one host aircraft, the aerial dispersant
holding tanks being configured as pseudo cargo containers; removably disposing a
dispersal regulator on the host aircraft; the dispersal regulator being coupled to the one or
20 more aerial dispersant holding tanks; and removably disposing an airborne dispersal
device on the host aircraft, the airborne dispersal device being coupled to the dispersal
25 regulator.

In another respect, disclosed herein is an aerial dispersant holding tank for use
30 within a passenger compartment of a host aircraft. The aerial dispersant holding tank

may be configured to be removably installed within the passenger compartment through a passenger door of the aircraft.

BRIEF DESCRIPTION OF THE DRAWINGS

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FIG. 1 is a simplified perspective view of modular pseudo cargo containers according to one embodiment of the disclosed systems and methods.

10 **FIG. 2** is a simplified perspective view of modular pseudo cargo containers according to another embodiment of the disclosed systems and methods.

FIG. 3 is a simplified perspective view of modular pseudo cargo containers according to another embodiment of the disclosed systems and methods.

15 **FIG. 4** is a simplified perspective view of a dispersal equipment pallet according to one embodiment of the disclosed systems and methods.

20 **FIG. 5** is a simplified cut-out perspective view of components of an aerial dispersion system installed in an aircraft according to one embodiment of the disclosed systems and methods.

FIG. 6 is a simplified block diagram of an aerial dispersion system according to one embodiment of the disclosed systems and methods.

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DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

30 **FIG. 1** illustrates aerial dispersant holding tanks **100** that may be employed in one embodiment to temporarily modify an aircraft, such commercial or military wide-body aircraft, for the aerial dispersement of materials. **FIG. 1** shows two aerial dispersant holding tanks **100** positioned in a front end-to-rear end relationship as they may be deployed within the baggage or cargo hold of an aircraft. However, it will be understood

that any number of such tanks 100 may be flexibly employed in a given aircraft as may be desirable or required to fit the needs of a given application. In this regard, a greater number of tanks 100 may be employed in aircraft having longer cargo holds and higher lift capacities, and/or in those situations where it is desirable to provide a relatively large volume for carrying dispersant material. A smaller number of tanks 100 may be employed in smaller aircraft and/or in situations where it is desirable to provide a relatively smaller volume for carrying dispersant material. For example, in the latter situation it may be desirable to reserve cargo room for carrying personnel or other types of cargo related to the aerial dispersant task at hand.

As illustrated in **FIG. 1**, each of aerial dispersant holding tanks 100 are configured as pseudo-cargo containers, *i.e.*, having outer dimensions that correspond to dimensions of conventional cargo containers that are employed in the side-loading cargo systems of wide body aircraft, such as 747, 767, 777, MD-11, C-5 and C-141 aircraft. As shown, such cargo containers may have sides with a shape complementary to the interior dimensions and shape of the aircraft baggage or cargo hold. By configuring tanks 100 as pseudo-cargo containers enables tanks 100 to be easily loaded and unloaded from the baggage or cargo holds of an aircraft using the same equipment and methods employed for loading and unloading conventional cargo containers from the aircraft. In this regard, the cargo systems of such aircraft are designed to load the cargo containers from the side of the aircraft through one or more cargo doors into the baggage or cargo hold of the aircraft, where the containers are received upon suitably configured surface 90 (*e.g.*, track, rails, rollers, *etc.*) upon which the cargo containers may be slidably or rollably transported forward or rearward in a direction parallel to the longitudinal axis of the aircraft fuselage and stacked in end to end manner. Once loaded, the cargo containers may be secured in this end-to-end relationship for the duration of the flight, or until otherwise necessary to remove the cargo containers from the aircraft. Unloading of the cargo containers from the aircraft may proceed in a fashion that is substantially reverse to the manner employed in the container loading process.

Although **FIG. 1** illustrates one exemplary embodiment of aerial dispersant tanks that are dimensionally configured for use as pseudo cargo containers with one type of conventional cargo container system and aircraft cargo hold configuration, it will be understood that aerial dispersant holding tanks may be alternatively configured in other embodiments to have other suitable dimensions and/or shapes as may be required for use as pseudo cargo containers with other types of cargo handling systems and/or aircraft cargo hold configurations. Furthermore, it will be understood that the exemplary “forward” and “rearward” notations used in **FIG. 1** are employed only to facilitate understanding of how tanks **100** of the disclosed systems and methods may interrelate within an aircraft in one exemplary embodiment. It is possible in other embodiments that tanks **100** may be oriented in the opposite direction within an aircraft, and/or that one or more of the illustrated feature of tanks **100** may be alternatively and operationally configured on the opposite end or other surfaces of such tanks in a manner that allows the tanks to be suitably employed in the disclosed aerial dispersant systems in a manner as described elsewhere herein.

Still referring to **FIG. 1**, aerial dispersant holding tanks **100** may be configured with a substantially hollow interior **118** for holding liquid and/or solid aerial dispersant material, *e.g.*, fire retardant/extinguishing material, oil dispersant material, bio-remediation material, fertilizer material, herbicide material, defoliant material, pesticide material, *etc.* In this regard, the types of materials and wall thicknesses employed in the construction of tanks **100** may be selected to fit the characteristics of a given aerial dispersion application (*e.g.*, constructed of chemical resistant materials, constructed with increased wall thickness to handle pressurization of the tank, constructed of lightweight materials such as aluminum or plastic to reduce system weight, *etc.*). Examples of materials that may be employed as aerial dispersant materials for fire fighting purposes include water or chemicals (*e.g.*, powders, liquid concentrates, *etc.*) that are mixed with water immediately prior to use. Examples of types of such chemicals include, but are not limited to, surfactants and fire retardant, fire suppressant or fire extinguishing chemicals. Specific examples of such chemicals include, but are not limited to, phosphate and ammonium-based compounds, which may also be mixed with dye markers for visibility.

Although not shown, the interior 118 of tanks 100 may be baffled as necessary to prevent side-to-side and/or forward-to-rearward sloshing or settling of the tank contents during take-off, landing and flight operations. Further, the interior of tanks 100 may be optionally configured with a cylindrical, spherical or other pressure-containing shape in those embodiments where tanks 100 are to be pressurized for enhancing material flow during dispersement. In one exemplary embodiment, tanks 100 may be of a collapsible configuration (*e.g.*, constructed of metal or composite material) to reduce storage area and to facilitate ease of transport from location to location when not in use.

In the illustrated embodiment, each of aerial dispersant holding tanks 100 includes two rearward-facing dispersant material flow openings 110 and two complimentary forward-facing dispersant material flow openings 112 that are dimensionally configured on the same centerlines 111 so as to sealably mate when adjacent tanks are rolled or otherwise positioned in end-to-end relationship within the cargo hold of an aircraft. Once so mated, flow openings 110 and 112 are configured to provide communication between adjacent tanks so that a flow path is provided that allows dispersant material to flow from one tank to another adjacent tank. Sealable mating between a given flow opening 110 and corresponding flow opening 112 may be provided using any sealing mechanism suitable for proving a leak-free connection between the interiors 118 of adjacent tanks. In this regard, it may be desirable that the flow openings automatically seal when adjacent tanks are assembled in end-to-end relationship (*e.g.*, using mating polished surfaces, O-ring seals, *etc.*), although it is also possible that threaded or other manipulatable or connections may alternatively be employed. It will be understood that an aerial dispersant holding tank may be configured with flow openings on only one end of the tank (*e.g.*, the rear end of the tank) so that it may be positioned on the terminal end of a material containment system formed from an interconnected group of material holding tanks. Alternatively, a terminal container may be provided by covering flow openings on one end of the tank with blind flanges, or by closing off flow openings one end of the tank using externally or internally provided valves.

It will be understood that the illustrated flow opening configuration of **FIG. 1** is exemplary only, and that any number and/or configuration of flow openings may be employed that are suitable for providing sufficient tank-to-tank flow characteristics (*e.g.*, fluid dynamics) during material loading and unloading operations (*e.g.*, during ground loading of the material and during aerial dispersment of the material) to meet desired or required flow capabilities. For example, it is usually desirable that sufficient flow capability exist between adjacent tanks to meet desired aerial dispersion rates under anticipated material dispersion conditions (*e.g.*, baggage or cargo hold attitude with respect to the horizontal, pressurized or unpressurized condition of aerial dispersant holding tanks, input pressure requirements of pump/s or other material transport equipment employed within the aerial dispersion system, liquid viscosity or slurried condition of material held within the tanks, solid/powered condition of material held within the tanks, *etc.*). In this regard, a single flow opening or more than two flow openings may be provided on one end surface of a tank, non-cylindrical shaped flow openings may be employed, and/or flow openings may be positioned in different locations on the tank ends than is illustrated in **FIG. 1**.

Optional flow control and/or metering equipment may also be provided in conjunction with one or more aerial dispersant holding tanks of an aerial dispersion system to provide positive control and/or metering of materials such as liquids that may be contained within the tanks. For example, each aerial dispersant holding tank **100** of **FIG. 1** is shown provided with an internal flow control and monitoring subsystem **114** that may be configured to control and/or meter flow of dispersant material between adjacent tanks **100** through flow openings **110** and **112**. For example, a flow control and monitoring subsystem **114** may include automated valves for regulating material flow through flow openings **110** and **112** between tanks **100**, and/or flow metering devices that measure flow of material through flow openings **110** and **112** between tanks **100** and provide a flow rate signal to a system operator and/or control subsystem. In this regard, flow control between tanks may be implemented to ensure sufficient flow of material to achieve adequate aerial dispersment rates while at the same time controlling distribution of materials within the tanks of the aerial dispersion system.

Flow control and monitoring subsystem **114** may also be configured to counteract undesirable shifts in aircraft center of gravity when tanks **100** are loaded or partially loaded with dispersant material, *e.g.*, by transferring material between tanks **100** as needed. This may be accomplished in one embodiment using localized sensors and valves to provide local control, and/or in response to centralized control signals from a system operator and/or control subsystem. Flow control and monitoring subsystem **114** may also include emergency shut down and/or other fail safe flow control equipment (ESD equipment) to control or shut-off material flow between tanks **100** during ground or airborne operations, for example, during inadvertent separation of two adjacent tanks **100**, upon development of a leak in the material containment or material dispersal subsystems of the aerial dispersion system, *etc.* Such ESD equipment may be automatically actuated locally or by a central control subsystem, and/or manually actuated by a system operator. Although illustrated as equipment internal to tanks **100**, it will be understood that a portion or all components of a flow control and monitoring subsystem **114** may be externally mounted to a tank **100**.

In one exemplary embodiment, flow control and monitoring equipment such as flow control and monitoring subsystems **114** may optionally include material transport and/or tank pressurization devices that may be present to facilitate transfer of liquid, slurried or solid material/s between adjacent tanks during ground loading of dispersant materials into the aerial dispersant holding tanks and/or during ground or airborne unloading of the aerial dispersant tanks. Examples of such material transport and/or pressurization devices include, but are not limited to, pumps, augers, blowers, compressors, *etc.* Such material transport and/or pressurization devices may be controlled by a system operator and/or control subsystem or may be controlled locally by sensors mounted within the same tank as the material transport and/or pressurization device/s.

Securing features may be optionally employed to selectably secure adjacent tanks to each other in end-to-end relationship within the baggage or cargo hold of an aircraft.

For example, in the illustrated embodiment of **FIG. 1**, tanks **100** are provided with securing features in the form of front latches **106** and complementary rear latches **108**, which may be configured to releasably secure respective front and rear ends of adjacent tanks **100** to each other via mechanical, electro-mechanical or other suitable latching mechanism and in a position such that mating flow openings (*e.g.*, flow openings **110** and **112**) of the adjacent tanks **100** are disposed in sealably mated condition. Securing features of adjacent tanks may be configured to mate and secure to each other in any fashion suitable for securing the adjacent tanks to each other. For example, securing features of adjacent tanks may be configured to automatically mate and lock together upon contact during tank loading operations. Likewise, securing features of adjacent tanks may be configured to release and separate from each other in any suitable manner, for example during tank unloading operations, *e.g.*, manual release, automatic release via electro-mechanical means, *etc.*

Alignment features may also be optionally provided. For example, as illustrated in **FIG. 1**, each of aerial dispersant holding tanks **100** may be provided with first alignment features (*e.g.*, rear alignment pins **102** on rear end of a tank **100**) that are configured to be received in corresponding second alignment features dimensionally configured on the same centerlines **101** (*e.g.*, corresponding front alignment receptacles **104** on the front end of an adjacent tank) to facilitate proper end-to-end alignment of the tanks **100** once they are positioned within the baggage or cargo hold of an aircraft.

In one embodiment, it is possible that one or more alignment features may also be provided with electrical connectors for communicating sensor and control information between the individual tanks of a system and a system operator and/or control subsystem. For example, electrical conductors and connectors (not shown) may be provided that are operable to interconnect tank sensors (*e.g.*, tank contents level sensors, tank temperature sensors, tank pressure sensors, *etc.*) and/or flow control and metering equipment of adjacent individual tanks when the alignment features are engaged. Alternatively, such systems may be interconnected in any other suitable manner, *e.g.*, by separate and/or external wiring and connectors, by wireless radio or optical signals, *etc.* It is also

possible that one or more alignment features may also be provided with conduit and conduit connectors (not shown) for transporting materials (*e.g.*, such as pressurized gas and/or chemicals) between a source of such materials and the individual tanks of the system. Alternatively, separate and/or external conduits and conduit connectors may be provided for transporting materials in a similar manner. In other embodiments, it is possible that alignment, tank securing and/or flow opening features may be combined into a single type of feature, *e.g.*, combined alignment and securing pin, combined alignment and securing latch, combined flow opening and latch, *etc.*

In an alternate embodiment, aerial dispersant holding tanks may be configured with a segmented interior for segregating dispersant materials held within the interior of the tanks. This may be desirable, for example, to provide the holding capacity for two or more different materials (*e.g.*, that may be mixed or otherwise combined prior to aerial dispersement) and/or to provide separate volumes of dispersant materials, *e.g.*, to be dispersed at different times (*e.g.*, as separate steps of an aerial dispersement treatment or for different types of aerial dispersement treatments). **FIG. 2** illustrates one example of such an embodiment in which aerial dispersant holding tanks **100** may be configured with tank dividers **116** that separate the substantially hollow interior of each tank **100** into two separate holding compartments **118a** and **118b**. In such an embodiment, flow openings **110a** and **112a** may be provided for interconnecting compartments **118a**, and flow openings **110b** and **112b** may be provided for interconnecting compartments **118b**. Flow control and monitoring subsystems **114** may be configured in such an embodiment to control and/or monitor material flow through flow openings **110a** and **112a** in a manner separate and independently from flow openings **110b** and **112b**. Although two separate holding compartments are illustrated in **FIG. 2**, it will be understood that three or more separate holding compartments may be similarly provided using any suitable segmented interior configuration.

FIG. 3 illustrates one exemplary embodiment of an aerial dispersion system **300** that may include one or more aerial dispersant holding tanks **100** positioned in a front end-to-rear end relationship with a dispersal equipment container **301** that may be

configured as a pseudo-cargo container and deployed within the baggage or cargo hold of an aircraft in a manner as previously described. As illustrated, dispersal equipment container 301 may be positioned within the baggage or cargo hold of the aircraft adjacent a cargo opening that may be, for example, the same cargo opening through which tanks 100 and container 301 are loaded and unloaded from the baggage or cargo hold.

Dispersal equipment container 301 is illustrated having an aerial dispersant outlet 303 coupled to an aerial spraying boom 310 through dispersant conduit 306 extending through opening 314 within a pseudo cargo door 308. In this regard pseudo cargo door 308 may be configured for temporary installation in place of a conventional cargo door of the aircraft during aerial dispersement operations. As shown, aerial spraying boom 310 includes spray outlets or nozzles 312 for aerially dispersing material supplied by dispersal equipment container 301, although it will be understood that the illustrated aerial spraying boom configuration is exemplary only and that any other type and/or configuration of airborne dispersal device suitable for spraying or otherwise aerially dispersing a particular material/s for a particular application may be employed.

As shown in FIG. 3, dispersal equipment container 301 may be internally configured with a dispersal regulator 302 coupled to at least one flow opening 112 of container 302. Dispersal regulator 302 may include, for example, one or more material transport devices and/or valves configured for transferring material from aerial dispersant holding tanks 100 under sufficient pressure to aerial spraying boom 310. In this regard, dispersal regulator 302 may be as simple as a valve for controlling gravity flow of aerial dispersant from tanks 100 (that may be pressurized or unpressurized) to boom 310, or may optionally include a material transport device such as a pump for pumping liquid aerial dispersant from tanks 100 to boom 310 at a desired pressure and/or flow rate. In either case, dispersal regulator 302 may be configured to selectively disperse material upon control signal or manual actuation, *e.g.*, so that dispersant material contained in tanks 100 may be dispersed as two, three or more multiple loads during a single airborne sortie.

In one exemplary embodiment, dispersal regulator **302** may be configured for transferring dispersant material into tanks **100** during ground loading operations, *e.g.*, through dispersant conduit **306**. Alternatively, dispersal equipment container **301** may include a separate opening, conduit, and/or equipment (not shown) for this purpose. It
5 will be understood that a dispersal equipment container may be configured in various ways as needed or desired for a particular aircraft or aerial dispersion mission. For example, a dispersal equipment container may be configured with multiple aerial dispersant outlets, *e.g.*, for coupling to multiple aerial spray booms on one or both sides of an aircraft. It is also possible that a dispersal equipment container may be configured
10 with flow openings on both front and rear ends to allow connection with dispersant holding tanks on both ends. In such a case, one or more aerial dispersant outlets may be provided on the sides or top of the dispersal equipment container, rather than the end.

As illustrated, dispersal equipment container **301** may also be configured with
15 other auxiliary equipment **304** that may be include, for example, one or more devices selected or otherwise suitable for accomplishing the needs of the particular aerial dispersion task at hand. For example, auxiliary equipment **304** may include compression equipment (*e.g.*, for providing pressurized gas to tanks **100**), mixing equipment (*e.g.*, for mixing two or more different materials taken from separate sources just prior to
20 dispersal), foaming equipment (*e.g.*, that is coupled to a compressor or other source of pressurized gas for foaming a material prior to dispersal), *etc.* Auxiliary equipment **304** may also include pumping and/or valving coupled to at least one flow opening **112** of container **301** for use during material loading operations. Dispersal unit **302** and/or auxiliary equipment **304** of container **301** may be controlled by a system operator and/or
25 control subsystem, *e.g.*, during aerial dispersement operations and/or ground loading operations.

It will be understood that dispersal equipment container **301** represents just one exemplary dispersal equipment configuration that may be implemented in aerial
30 dispersion systems disclosed herein. In this regard, dispersal equipment may be provided in any configuration suitable for coupling to one or more material holding tanks and

capable of performing one or more the dispersal equipment feature/s described above with relation to dispersal equipment container **301**. Alternatively, one or more dispersal equipment components may be provided in a configuration integral to a material holding tank, *e.g.*, coupling to other dispersal equipment components in a dispersal equipment container, or for direct coupling without dispersal equipment container to other components of an aerial dispersion system such as a dispersant conduit/aerial spraying boom.

For example, **FIG. 4** illustrates a dispersal equipment pallet **400** that may be alternatively implemented in an aerial dispersion system with the same features described above for dispersal equipment container **301**. As illustrated, pallet **400** may include dispersal regulator **402** (*e.g.*, valve/s and/or pump mechanism/s or other material transport device/s) that may be coupled to at least one flow opening of an aerial dispersant holding tank **100** via opening **403** that may serve for material transfer out of tanks **100** during aerial dispersant operations and optionally for material transfer into tanks **100** during ground loading operations. Dispersal regulator **402** is illustrated having an aerial dispersant outlet **404** coupled to an aerial spraying boom **310** through dispersant conduit **306** extending through opening **314** within a pseudo cargo door **308**. As with dispersal regulator **302** of **FIG. 3**, dispersal regulator **402** may include, for example, one or more material transport devices and/or valves configured for transferring material from aerial dispersant holding tanks **100** under sufficient pressure to aerial spraying boom **310**. Dispersal equipment pallet **400** may also include auxiliary equipment (not shown) similar to that described in relation to dispersal equipment container **301** of **FIG. 3**.

FIG. 5 illustrates an aircraft-based material dispersion system **506** having an aerial dispersion system installed within a host aircraft **500** according to one embodiment of the disclosed systems and methods. Host aircraft **500** may be any passenger, cargo or military aircraft having a baggage or cargo hold (or, as will be described further herein, having a passenger compartment) suitable for containing components of the disclosed system, for example, a wide-body aircraft such as 747, 767, 777, MD-11, C-5, C-141, *etc.* In **FIG. 5**, host aircraft **500** is shown with a section **502** cut out of fuselage **504** so

that individual aerial dispersant holding tanks **100** are visible as loaded and operationally assembled together within the baggage or cargo hold of host aircraft **500** to form an aerial dispersion system, *e.g.*, in a manner as previously described. Also shown is dispersal equipment container **301** that is positioned adjacent pseudo cargo door **308** and coupled to aerial spraying boom **310** which extends outwardly from door **308** for purposes of aerially dispersing materials contained in tanks **100**. As previously described, pseudo cargo door **308** may be installed in place of a conventional cargo door within a pre-existing cargo opening in the fuselage of the aircraft, *e.g.*, the same cargo opening through which holding tanks **100** and equipment container **301** may be loaded and unloaded from the aircraft.

It will be understood that the illustrated embodiment of **FIG. 5** is not drawn to scale, and is exemplary only. In this regard, it will be understood that the number and configuration of tanks may vary according to particular aircraft and mission. Furthermore, it will be understood that multiple pseudo cargo doors having multiple aerial spray booms may be positioned on one or both sides of an aircraft fuselage to maximize aerial spray pattern. This may be the case, for example, when employing aircraft having multiple cargo door openings on one or both sides of the aircraft fuselage. Furthermore, it is possible that multiple but separate sub-groups of holding tanks with associated dispersal equipment container or pallet may be installed within an aircraft to form multiple independent aerial dispersion systems, *e.g.*, for independently dispersing the same or different types of materials. Various other combinations are possible, for example, an equipment dispersal container may be positioned at the forward end of a group of interconnected tanks rather than at the aft end of the group of tanks, or equipment dispersal containers may be positioned at both forward and aft ends of a group of interconnected holding tanks for dispersing materials from each ends of the group of tanks through cargo doors positioned adjacent each dispersal container.

In one embodiment, a conventional commercial or military aircraft **500** may be temporarily converted for aerial dispersion operations as follows. On the ground, aerial dispersant holding tanks **100** and one or more dispersal equipment container/s **301** may

be sequentially loaded into the baggage or cargo hold of aircraft 500 through one or more cargo openings in fuselage 504 using conventional cargo loading equipment and techniques. Conventional cargo door/s may also be replaced with pseudo cargo door/s at this time. Once loaded and interconnected within the baggage or cargo hold, aerial dispersion holding tanks 100 may be filled with one or more aerial dispersant materials as suitable or desired for a particular aerial dispersion mission.

Loading of aerial dispersion system equipment into an aircraft may or may not take place at the same time and at the same ground base as loading of material dispersant materials into the holding tanks. In this regard, it is possible that one or more aircraft may be flown to one or more designated central bases where aerial dispersion system equipment is kept and maintained, and where the components of the aerial dispersion system may be loaded into the aircraft to modify the aircraft for aerial dispersion purposes. The aircraft may then be flown to one or more designated local bases for loading of aerial dispersant material/s, *e.g.*, at an area near or adjacent the aerial dispersant target, such as near a wildfire to be suppressed. After loading with dispersant material/s, the aircraft may fly one or more aerial dispersion sorties over the target area as necessary or desired, with reloading of aerial dispersant material taking place at the local bases as necessary. When the objective of the aerial dispersion mission is completed, the aircraft may be flown back to the central base/s for unloading of the aerial dispersion equipment from the baggage or cargo hold of the aircraft so as to de-modify the aircraft and return it to its conventional passenger or cargo configuration. The forgoing description is exemplary only, and it will be understood that the flexibility of the disclosed systems and methods make possible a variety of ways in which aircraft may be modified, employed, and de-modified for aerial dispersion purposes.

FIG. 6 is a simplified block diagram of an aerial dispersion system 600 according to one embodiment of the disclosed systems and methods. As shown, aerial dispersion system 600 includes multiple subsystems 602, 604, 606, 608, 610 and 612 that may be operably coupled together and interfaced with host aircraft systems 616 for aerial dispersion operations. Ground handling and support subsystem 614 may include ground

equipment and personnel positioned at a central or local base and utilized for installing/uninstalling equipment components of an aerial dispersion system, and for loading/unloading material dispersant from an installed aerial dispersion system.

5 Still referring to **FIG. 6**, material containment subsystem **610** may include aerial dispersant material holding tanks and associated equipment previously described herein, and material dispersal subsystem **612** may include dispersal equipment container/pallet, pseudo cargo door, aerial spray boom and associated equipment previously described herein. As previously described, components of subsystems **610** and **612** may be
10 monitored and/or controlled by a system operator and/or control subsystem, represented in **FIG. 6** by control subsystem **604**. Components of subsystems **602**, **604**, **606** and **608** may be provided in any suitable manner suitable for temporary installation in a host aircraft (*e.g.*, palletized for loading in baggage/cargo hold or main cabin of host aircraft, or installed in a manner as described elsewhere herein), and may be operably coupled
15 together and/or coupled to various systems of a host aircraft via hardware and/or wireless connection. It will be understood that the illustrated components of aerial dispersion system **600** are exemplary only, and that other combinations of subsystems are possible (*e.g.*, using other subsystems and/or only a portion of the illustrated subsystems such as only subsystems **610** and **612**).

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 Also illustrated in **FIG. 6** is navigation subsystem **602** which may provide navigational information to control subsystem **604** that is based on navigation-related signals received from the ground, received from satellites, and/or received from the navigation systems of the host aircraft. In this regard, navigation subsystem **602** may
25 provide flight characteristic information for the host aircraft (*e.g.*, current aircraft location, altitude, attitude, speed, *etc.*), meteorological information at altitude for the host aircraft (*e.g.*, winds, temperature, humidity, *etc.*), flight plan information (*e.g.*, directions to material dispersant drop point, recovery point, local home base, *etc.*). In one exemplary embodiment, navigation subsystem **602** may be configured with a subsystem
30 computer or processor to calculate various operational parameters (*e.g.*, optimum

material drop point, optimum flight plan, *etc.*) based on flight characteristic information, meteorological information, *etc.*

Still referring to **FIG. 6**, communications subsystem **606** may provide communication information to control subsystem **604** from ground and/or other airborne sources to control subsystem **604** and vice-versa. In this regard, communications subsystem **606** may be coupled to existing antennae devices of the host aircraft and may receive a variety of information communicated from antennas of ground base controllers and/or other host aircraft including, but not limited to, voice or text communications from ground personnel or flight crews of other host aircraft, position and flight plan of other host aircraft, volume of material dispersant remaining in other host aircraft, position of ground personnel, meteorological information for the target area from ground personnel or ground weather sensors, up to date target location, information or orders concerning flight formation and coordinated aerial dispersant drops by multiple aircraft, *etc.* Communications subsystem **606** may also be employed to transmit information from control subsystem **604** to other host aircraft or ground stations. Such transmitted information may include, for example, any of the information received by control subsystem **604** from host aircraft systems **616** and/or from one or more subsystems **602**, **606**, **608**, **610** and **612**.

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Sensor subsystem **608** may include any one or more sensor devices suitable for providing sensor information to control subsystem **604** that may be used to characterize a material dispersant target or conditions related to same. Examples of such sensor devices include, but are not limited to, real time visual information, electro-optic information, infra-red imaging, thermal imaging, radar imaging, radio receivers, *etc.* In one exemplary embodiment, one or more components of a sensor subsystem **608** may be provided as a movable turret or in another suitable configuration that may be temporarily installed on a host aircraft as part of pseudo wheel well door, in a manner similar to the pseudo cargo door described elsewhere herein. One specific example of such a sensor subsystem is a electro-optic/infra-red (“EO/IR”) turret that may be incorporated into a

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pseudo wheel well door and utilized in a wildfire situation visualize the fire area and to identify fire hot-spots.

In one exemplary embodiment, control subsystem **604** of aerial dispersion system **600** may be implemented with command, control and display capabilities, although it is possible that any one or more of these capabilities may be implemented in other embodiments separately or in combination with other capabilities. To implement command, control and display capabilities, control subsystem **604** may be configured to receive and share information and control signals with each of subsystems **602**, **606**, **608**, **610** and **612**, as well as one or more host aircraft systems **616**. Control subsystem **604** may also be provided with one or more computers or processors, and/or one or more display/s and control interface/s for use by a system operator/s on the host aircraft. In this regard, control subsystem **604** may receive and display information from each of the coupled subsystems to a system operator/s (*e.g.*, position tracking information on other host aircraft in an aerial dispersant fleet, status of aerial dispersion systems including material dispersant volume on other host aircraft in an aerial dispersant fleet, sensor video data characterizing conditions in the aerial dispersant target area, meteorological and flight characteristics for the host aircraft or various ground locations, location of radio or optical beacons or ground markers deployed in the aerial dispersant target area for target designation, laser targeting point for a dispersant material drop zone, flight path and aircraft formation information for conducting an aerial dispersant material drop, material containment subsystem sensor, volume and operating parameters on the same host aircraft, material dispersal subsystem sensor, flow rate and operating parameters on the same host aircraft, *etc.*)

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Control subsystem **604** may be employed, for example, to control flow control and monitoring subsystems of material containment subsystem **610** during dispersant material loading and aerial dispersment operations, *e.g.*, to support material transfer between material containment subsystem **610** and material dispersal subsystem **612** for aerial dispersant drops, to respond to emergency conditions, and to maintain a stable host aircraft center of gravity by preventing shifts in the dispersant material. Control

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subsystem 604 may also be employed to control material dispersal subsystem 612 during aerial dispersant drops, *e.g.*, to control type of material dispersed, material dispersal rate, mixing of dispersant materials, *etc.* Other control features that may be implemented by control subsystem 604 include control of sensor subsystem 608 to gather desired sensor information, control of communications subsystem 606 to transmit data or command information to ground or other host aircraft, control of host aircraft systems 616 including control of aircraft flight characteristics during aerial dispersant “bombing” run, *etc.*

It will be understood that the forgoing description of control subsystem 604 is exemplary only, and that other combinations of control, display and command features may be employed as may be desired or necessary for a given application. Furthermore, it will be understood that the control and command features may be completely manual (*e.g.*, via system operator/s), or may be partially or completely automated (*e.g.*, via computer or other processor/s). It is also possible that at least a portion of the control and/or command features for an aerial dispersion systems on a given host aircraft may be performed by equipment or personnel on another aircraft or the ground.

Although not shown, in an alternate and optional embodiment the passenger compartment of a host aircraft may be alternately or additionally employed to contain one or more modular components of an aerial dispersion system such as disclosed elsewhere herein (*e.g.*, pseudo cargo container/s, dispersal regulator, *etc.*). In this regard, the passenger seats or other equipment contained within the passenger compartment of a given aircraft may be partially or completely removed, and replaced with components of an aerial dispersion system that are configured with a shape complementary to the interior dimensions and shape of the passenger compartment, and/or that are otherwise configured with dimensions suitable to allow the aerial dispersion system components to be operably installed, secured and contained therein. In this regard, system components may be configured as pseudo cargo containers or in any other alternative shape or dimension suitable for installation in a passenger compartment. In one exemplary embodiment, one or more system components may be configured as pseudo-cargo containers having outer dimensions that correspond to dimensions of conventional cargo

containers adapted for installation and removal from an aircraft passenger compartment, for example, as described and illustrated in U.S. Patent No. 5,090,639, which is incorporated herein by reference.

5 For example, in one exemplary embodiment, aerial dispersion system components may be installed within all or a portion of the passenger compartment as an alternative to installation of aerial dispersion system components within the baggage or cargo hold of the aircraft. This may be done, for example, by providing one or more pseudo passenger door/s or pseudo emergency exit door/s that are configured with features similar to a
10 pseudo cargo door described elsewhere herein, *e.g.*, configured with an opening through which a dispersant conduit may extend to couple components of the passenger compartment-based aerial dispersion system to an aerial spraying boom or other dispersal mechanism outside the aircraft. In such an exemplary embodiment, the aerial dispersion system components may be configured to operate in a manner similar to the baggage or
15 cargo hold-based aerial dispersion system components described elsewhere herein.

 In another exemplary embodiment, aerial dispersion system components may be installed within all or a portion of the passenger compartment in addition to other aerial dispersion system components that are installed within all or a portion of the baggage or
20 cargo hold of the same aircraft. In such a dual-compartment installation (*i.e.*, when components are installed in both cargo and passenger compartments), the aerial dispersion system components in the passenger compartment may be implemented as a separate aerial dispersion system that operates or functions independently of the aerial dispersion system components installed within the baggage or cargo hold of the same
25 aircraft (*e.g.*, as a separate and independent system as described in the immediately preceding paragraph). Alternatively, the aerial dispersion system components installed in the passenger compartment may be implemented in combination or conjunction with aerial dispersion system components that are installed within the baggage or cargo hold of the same aircraft (*e.g.*, to operate as one aerial dispersion system formed by
30 components in positioned in both baggage/cargo hold and cabin/passenger compartments of the same aircraft). In the latter case, the baggage/cargo hold-based components may

be configured to be in fluid and/or electrical signal communication with the cabin/passenger compartment-based components of the system in any suitable manner, *e.g.*, through custom-made openings specifically made for that purpose and/or through existing conduits or openings disposed between the baggage/cargo hold and cabin/passenger compartment (*e.g.*, existing plumbing conduits or openings, electrical conduits or openings, access doors, *etc.*).

In the practice of the disclosed systems and methods, one or more aerial dispersion systems may be employed on one or more host aircraft for aerial dispersement of any material that is suitable for aerial dispersement, including any of the aerial dispersement materials and in any of the aerial dispersement tasks described elsewhere herein. In this regard, it is possible that only a single host aircraft may be modified with the disclosed aerial dispersion system and employed for aerial dispersion of materials. Although any type of aircraft having a baggage or cargo hold suitable for use with components of the disclosed systems may be employed, particular advantage may be realized by using high lift capacity aircraft (*e.g.*, aircraft having a gross carrying capacity of greater than or equal to about 100,000 pounds). For example, a typical 747 commercial aircraft has a gross carrying weight of about 140,000 pounds and is capable of carrying about 13,000 gallons of liquid dispersant material such as water. This is over four times the 3000 gallons carrying capacity of a typical aerial dispersant system aircraft now employed for purposes such as aerial firefighting. Thus, using the disclosed systems and methods to convert even a single high lift capacity aircraft for aerial dispersion tasks achieves a significant increase in material dispersant volume capacity.

However, in one exemplary embodiment a plurality of relatively high capacity aerial dispersion systems may be provided by installing these systems on a relatively large fleet of wide-body or other high lift capacity host aircraft. Such a fleet of host aircraft may be advantageously employed, for example, to protect high value targets (*e.g.*, populated areas, industrial areas, environmentally sensitive areas, wilderness areas, *etc.*) from threats such as large scale fires, large scale oil or chemical spills, biological hazards, radiation hazards, *etc.* In such an embodiment, a relatively large number of commercial

and/or military aircraft may be activated for temporary and short term use, for example, as part of the Civil Reserve Air Fleet ("CRAF"). Using the systems and methods disclosed herein, the activated aircraft may be modified in a relatively short period of time (*e.g.*, in less than about 8 hours) at one or more locations for an aerial dispersion role such as firefighting, oil spill containment/treatment, or neutralization of biological, chemical or radiation hazard. The aircraft may be loaded with material dispersant at one or more locations and then assembled as an airborne fleet for purpose of conducting a massive and coordinated multi-aircraft drop of aerial dispersant over the target area/s, with little or no support required from ground personnel such as fire jumpers or spotters. Upon completion of the aerial dispersion mission the aircraft may be demodified in a relatively short period of time (*e.g.*, in less than about 8 hours) at one or more locations and returned to prior commercial or military use.

Therefore, the disclosed systems and methods allow a large fleet of high lift capacity aircraft to be rapidly assembled and modified for aerial dispersion purposes. Such a fleet of modified high capacity aircraft may be coordinated and/or controlled in any manner suitable for optimally achieving the goals of the aerial dispersion task with minimal risk to the flight crews and aircraft. For example, multiple aircraft (*e.g.*, 12 to 15 747 aircraft) may be flown in a coordinated side-by-side or row formation over the targeted drop area, maximizing the aerial coverage of dispersant that may be provided to the drop area in a single pass. Alternatively or additionally, coordinated successive or sequential rows of one or more aircraft may immediately follow each other in trailing formation in the same pass over the targeted drop area to greatly increase the volume of dispersant material that may be applied to the target area in a short period of time. Aerial dispersion operations (*e.g.*, fleet formation, flight path and drop point for the material dispersant drop, *etc.*) conducted by a fleet of modified aircraft may be controlled, for example, by centralized ground or air control system or personnel using, for example, the aerial dispersion system components illustrated and described with respect to **FIG. 6** herein. The very large volume and continuous coverage area of dispersant material that may be so applied using such a fleet of high capacity aircraft, advantageously allows the material to be dispersed at a relatively high altitude (*e.g.*, greater than or equal to about

500 feet) and with a relatively stable and level flight attitude that does not overstress the aircraft structures.

5 Although the disclosed systems and methods may be used to disperse materials over target drop zones at relatively high altitudes and stable and level flight attitude, it may be desirable to adjust the nose to tail attitude of the aircraft during material drop to optimize gravity forces for fluid flow between material dispersant holding tanks and the aerial spray boom or other aerial dispersing device. This may be more desirable, for example, in the practice of those embodiments that employ gravity fluid flow.

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While the invention may be adaptable to various modifications and alternative forms, specific embodiments have been shown by way of example and described herein. However, it should be understood that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, 15 equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims. Moreover, the different aspects of the disclosed apparatus and methods may be utilized in various combinations and/or independently. Thus the invention is not limited to only those combinations shown herein, but rather may include other combinations.